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ENTRY ACQUISITION AND RADIO
VISIBILITY COMPUTER PROGRAM

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MANNNED SPACECRAFT CENTER
HOUSTON, TEXAS

BY

J.S. LINNEKIN
COURT F. BUELL

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RADIO VISIBILITY COMPUTER PROGRAM

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Jerry S. Linnekin
Court F. Buell*

September 1966

Goddard Space Flight Center
Greenbelt, Maryland

*Bendix Employee under contract to GSFC, Contract Number NAS-5-9870

GLOSSARY

θ_b	Antenna orientation angle wrt vehicle coordinates, in XZ vehicle plane.
ϕ_i	Antenna orientation angle wrt vehicle coordinates, in YZ vehicle plane.
ϕ_G	Geodetic latitude
λ_G	Geodetic longitude
ϕ_C	Geocentric latitude
λ_C	Geocentric longitude
h	Altitude above surface of earth
A_z	Vehicle azimuth angle
B	Vehicle bank angle — roll about velocity vector measured from local vertical.
X_B, Y_B, Z_B	Components of body coordinate system
X_L, Y_L, Z_L	Components of launch cartesian coordinate system
X_S, Y_S, Z_S	Station cartesian coordinates wrt earth system
α_T	Trim angle of attack — the angle between the velocity vector and the longitudinal vehicle axis.
γ	Flight path angle — the angle between the velocity vector and the local horizontal.
R_E	Equatorial radius of earth
\vec{R}_S, \vec{R}_{S_E}	Position vector — station wrt earth system
\vec{R}_V, \vec{R}_{V_E}	Position vector — vehicle wrt earth system
\vec{R}_{SV}	Position vector — vehicle wrt station

$\vec{R}_{SV E_j}^{\circ}$	Unit vector — station to vehicle
\vec{A}_i°	Unit vector — principal axis of antenna propagation for directional antenna
δ_{ij}	Antenna look angle — angle between \vec{A}_i° and $-\vec{R}_{SVE_j}^{\circ}$
ϵ, EL	Station elevation angle
$\left. \begin{matrix} \theta \\ \phi \end{matrix} \right\}$	Body fixed angles, referenced to launch coordinates, describing antenna radiation pattern
T_{B2G}	Body to geodetic coordinate transformation
T_{G2E}	Geodetic to earth coordinate transformation
T_{B2E}	Body to earth coordinate transformation
θ_A	Radiation half cone angle for directional antenna
δ_A	Aspect angle — angle between the negative of the station position vector and the longitudinal axis of the vehicle - degrees
δ_B	Velocity vector look angle — angle between the negative of the station position vector and the vehicle's velocity vector - degrees
\vec{V}	Vehicle relative velocity vector — (ft/sec)
R'	Distance from center of earth to station (km)

ENTRY ACQUISITION AND RADIO VISIBILITY COMPUTER PROGRAM

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SUMMARY

The Entry Acquisition and Radio Visibility Program requires as input tracking station locations and the time history of the entry vehicle's motion and orientation. The program provides the following information for each station:

1. Acquisition (azimuth and elevation) information for the tracking radars.
2. Antenna look angle information for up to eight vehicle-borne antennas (Ref. 1).
3. Blackout predictions for VHF, C-Band and S-Band radars.

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ENTRY ACQUISITION AND RADIO VISIBILITY COMPUTER PROGRAM

INTRODUCTION

This program was developed to enable the user to provide optimum tracking station locations (both ship and aircraft) for an entry vehicle. The program was used in support of Apollo AS-202 (Ref. 2). The acquisition information for the aircraft, the antenna look angles and blackout predictions in reference 2 were generated by this program.

I. Program Formulation

The equations in this report are taken directly from Refs. 1, 2, and 3 and are repeated here for convenience.

A. Coordinate Systems

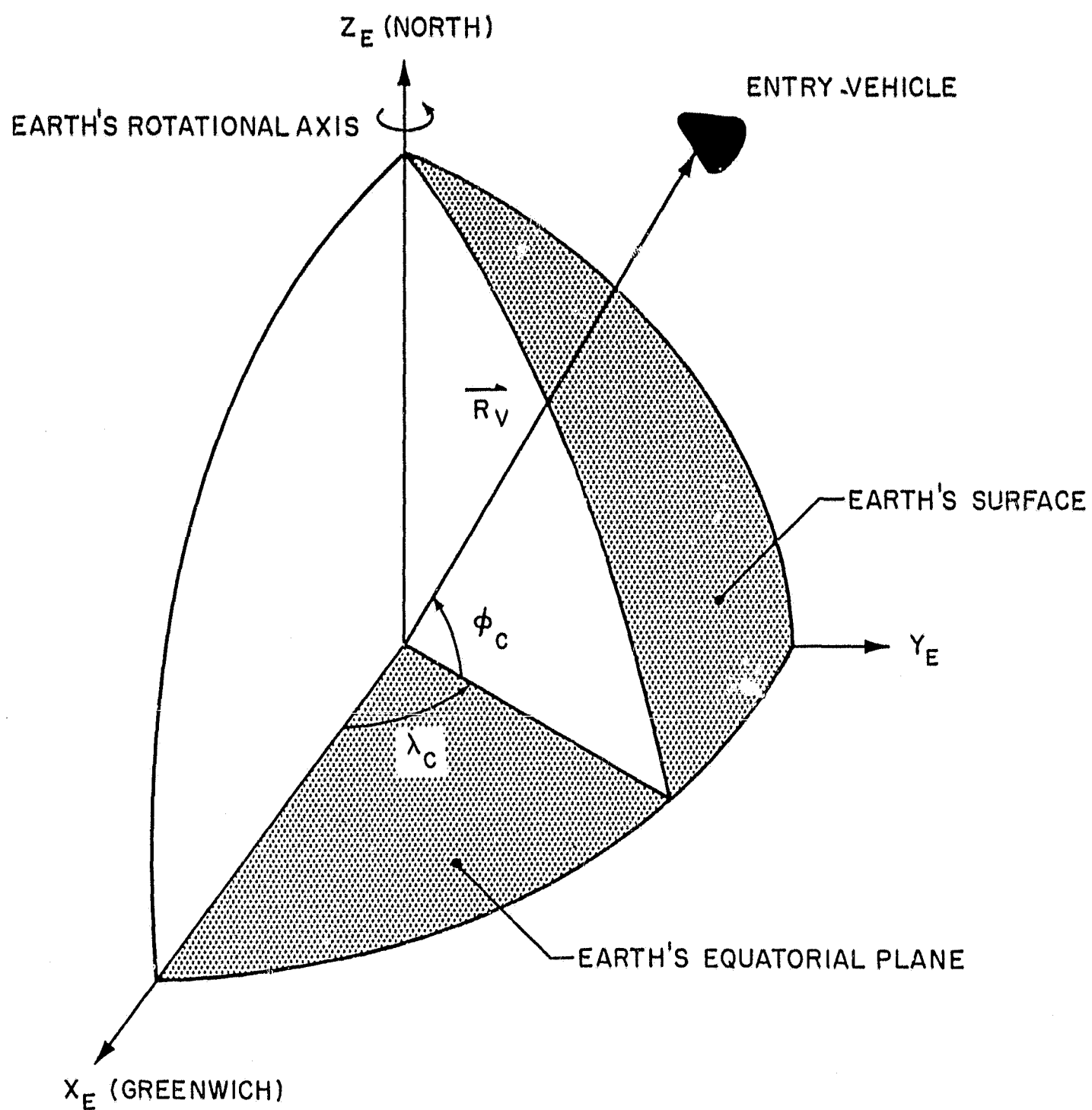
1. Earth Fixed Coordinate System (Fig. 1): A right hand orthogonal system that is attached to the earth and rotating with it. The Z axis is the rotational axis. The X and Y axis lie in the equatorial plane with the X axis pointing from the center of the earth to the Greenwich meridian.

2. Geodetic Coordinate System (Fig. 2): The geodetic coordinate system is a right handed orthogonal system with origin at the surface of the earth. Station locations are expressed in this frame in terms of ϕ_G , λ_G , and h .

3. Body Coordinate System (Fig. 3): This is the body coordinate system used in Ref. 3 and is attached to the body and rotating with it. The X axis is the Longitudinal axis of the body positive in the direction of motion. The Z axis is positive downward in a zero roll, zero flight path attitude with zero angle of attack. The Y axis completes the right handed orthogonal system.

B. "Radio Visibility"

1. Directional Antenna: The Antenna Look Angle (Ref. 1) is defined as the angle between the axis of propagation of a vehicle-borne antenna and the negative of the line of sight vector from an arbitrary radar station.



THIS SYSTEM IS ATTACHED TO THE EARTH AND ROTATING WITH IT

Figure 1—Earth Fixed Coordinate System

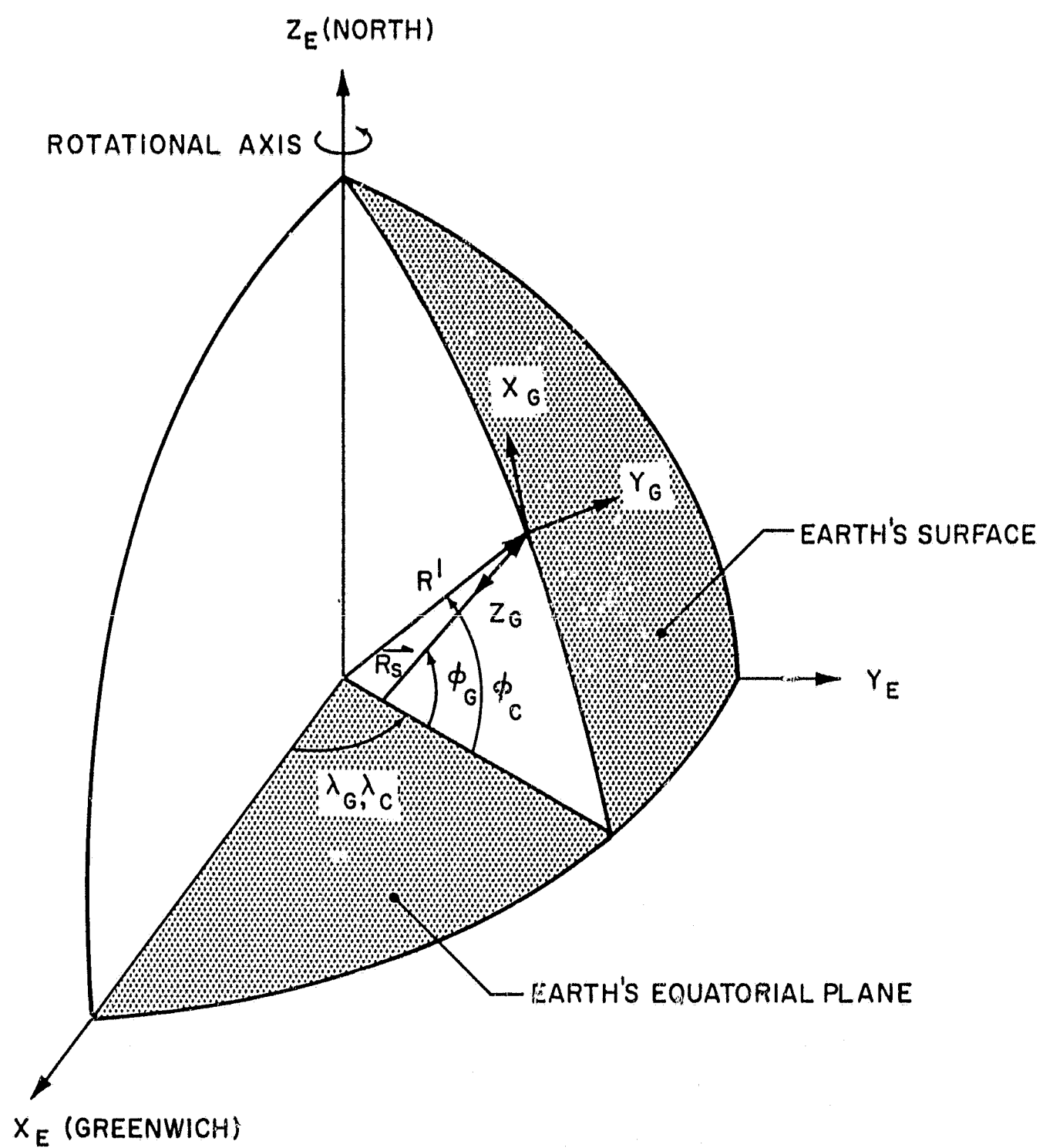


Figure 2—Geodetic Coordinate System

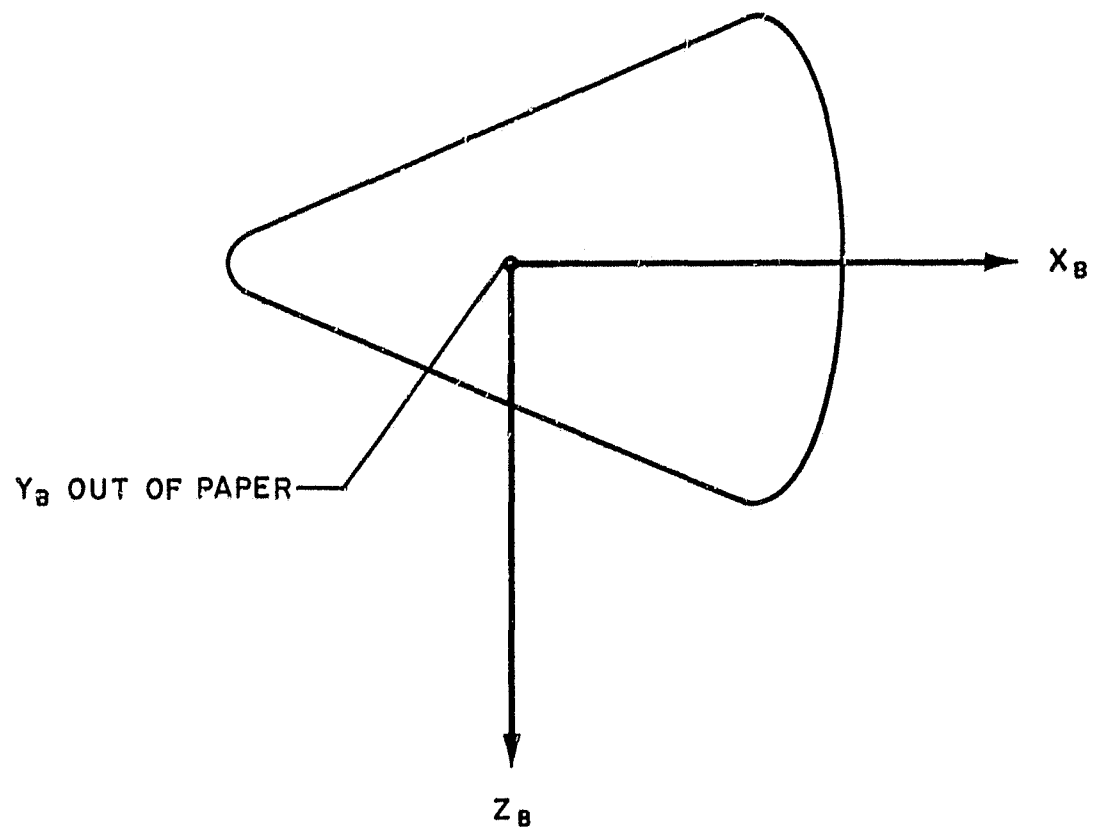


Figure 3--Body Coordinate System

$$\vec{A}_i^o = \sin \theta_b \vec{i} + \cos \theta_b \sin \phi_i \vec{j} - \cos \theta_b \cos \phi_i \vec{k} \quad (1)$$

is a unit vector analogous to the propagation axis of an antenna. It is expressed in the body axis system

$$\begin{bmatrix} X_B \\ Y_B \\ Z_B \end{bmatrix}_{(3 \times 1)}$$

by pitching about the Y_B axis through θ_b and rolling about the X_B axis through ϕ_i . During entry, the Apollo vehicle has a trim angle of attack. This is accomplished by pitching about the Y_B axis by α_T

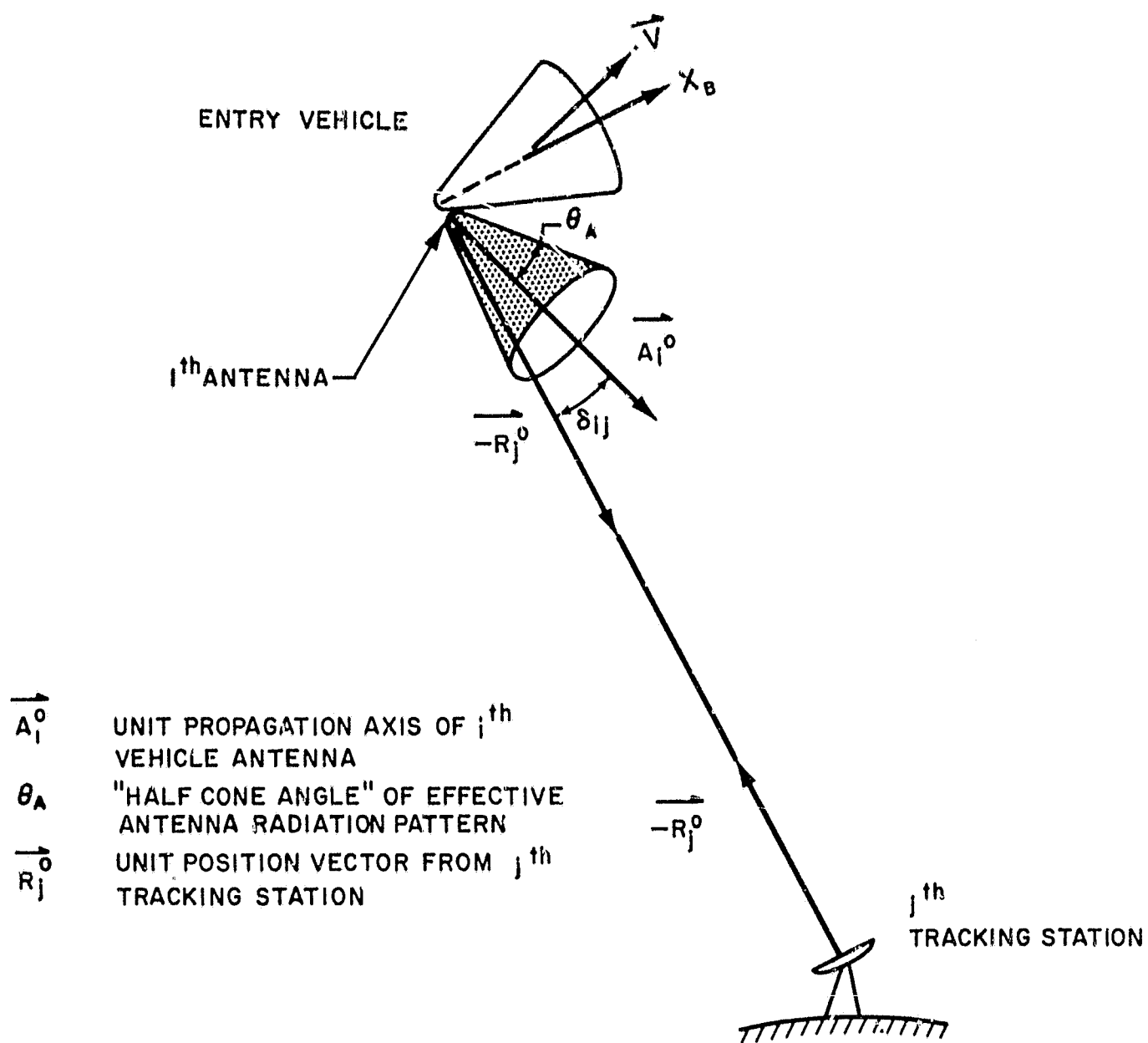


Figure 4—Antenna Look Angle δ_{ij}

$$T_{B2A} = \begin{bmatrix} \cos a_T & 0 & \sin a_T \\ 0 & 1 & 0 \\ -\sin a_T & 0 & \cos a_T \end{bmatrix}_{(3 \times 3)} \quad (2)$$

we now have

$$\vec{A}_{B_i}^0 = \begin{bmatrix} \cos a_T \sin \theta_b - \sin a_T \cos \theta_b \cos \phi_i \\ \cos \theta_b \sin \phi_i \\ -(\sin a_T \sin \theta_b + \cos a_T \cos \theta_b \cos \phi_i) \end{bmatrix}_{(3 \times 1)} \quad (3)$$

or

$\vec{A}_{B_i}^{\circ}$ is now transformed to the earth coordinate system (Fig. 1) by multiplying by T_{B2E}

$$\vec{A}_{E_i}^{\circ} = T_{B2E} \vec{A}_{B_i}^{\circ} \quad (4)$$

where

$$T_{B2E} = T_{G2E} T_{B2G} \quad (5)$$

with

$$T_{G2E} = \begin{bmatrix} -\sin \phi_G \cos \lambda_G & -\sin \lambda_G & -\cos \phi_G \cos \lambda_G \\ -\sin \phi_G \sin \lambda_G & \cos \lambda_G & \cos \phi_G \sin \lambda_G \\ \cos \phi_G & 0 & -\sin \phi_G \end{bmatrix}_{(3 \times 3)} \quad (6)$$

and

$$T_{B2G} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}_{(3 \times 3)}$$

where

$$a_{11} = \cos \gamma \cos A_z$$

$$a_{12} = -\sin A_z \cos B + \sin \gamma \cos A_z \sin B$$

$$a_{13} = \sin A_z \sin B + \sin \gamma \cos A_z \cos B$$

$$a_{21} = \cos \gamma \sin A_z$$

$$a_{22} = \cos A_z \cos B + \sin \gamma \sin A_z \sin B$$

$$a_{23} = -\cos A_z \sin B + \sin \gamma \sin A_z \cos B$$

$$a_{31} = -\sin \gamma$$

$$a_{32} = \cos \gamma \sin B$$

$$a_{33} = \cos \gamma \cos B$$

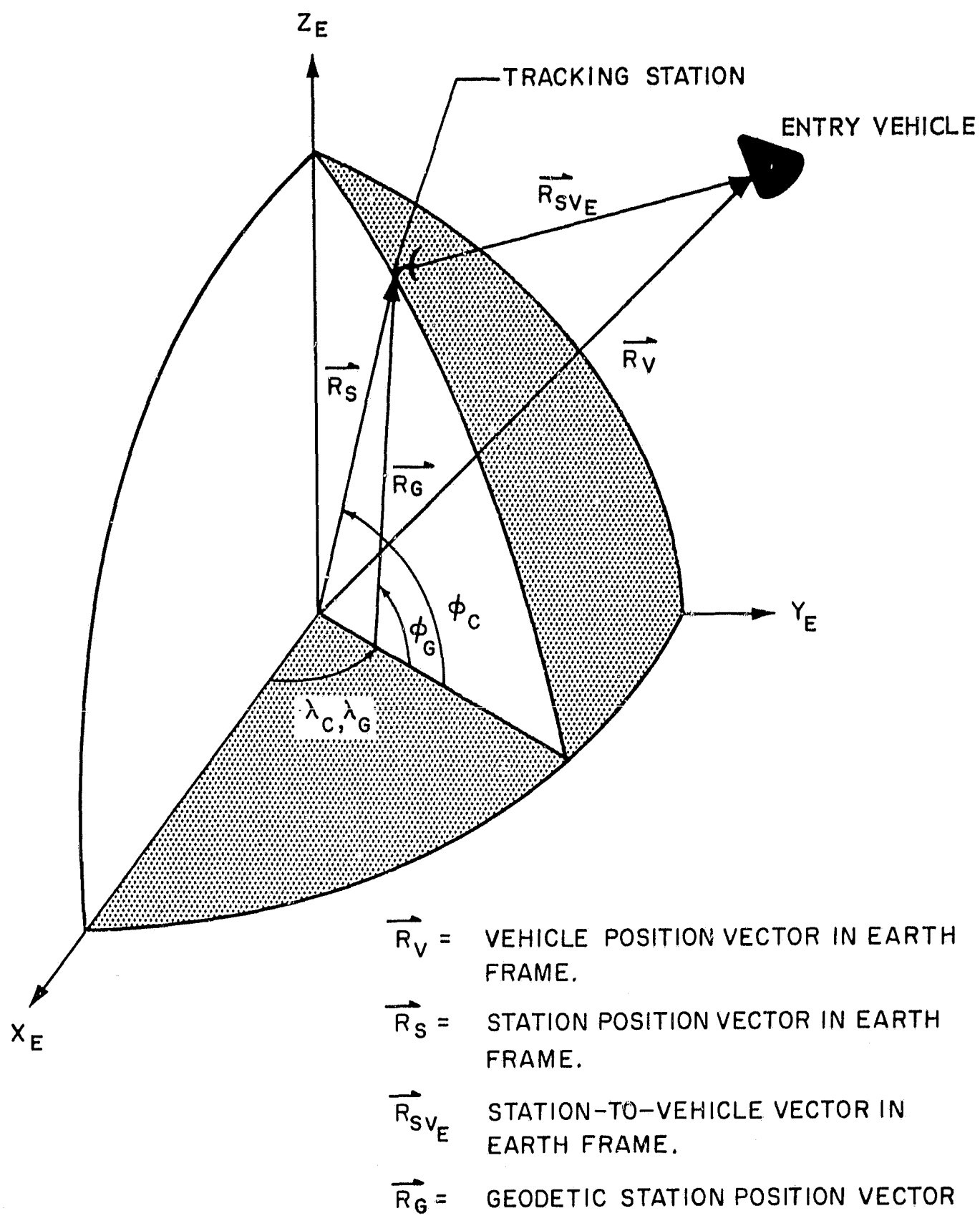


Figure 5—Station-Vehicle Relationships

or

The station location vector (Fig. 5) in the Earth Frame is

$$\vec{R}_S = R' \begin{bmatrix} \cos \phi_c \cos \lambda_c \\ \cos \phi_c \sin \lambda_c \\ \sin \phi_c \end{bmatrix}_{(3 \times 1)} \quad (8)$$

where

$$R' = \frac{ab}{\sqrt{b^2 \cos^2 \phi_c + a^2 \sin^2 \phi_c}} + h \quad (9)$$

with a and b being the semi major and semi minor axes of the earth, and h the altitude of the tracker. R_v , the vehicle position vector in the earth frame is input and we have the station to vehicle vector \vec{R}_{sv} expressed in the earth's frame as:

$$\vec{R}_{sv_E} = \vec{R}_v - \vec{R}_S \quad (10)$$

The antenna look angle may now be computed using equations (4) and (10) as

$$\delta_{ij} = \cos^{-1} \left(-\vec{R}_{sv_{E_j}}^o \cdot \vec{A}_{E_i}^o \right) \quad (11)$$

where the subscripts i and j denote the antenna number and station number respectively.

The criterion for a entry vehicle to be "radio" visible with respect to a given radar station is

$$\delta_{ij} \leq \theta_A \quad (12)$$

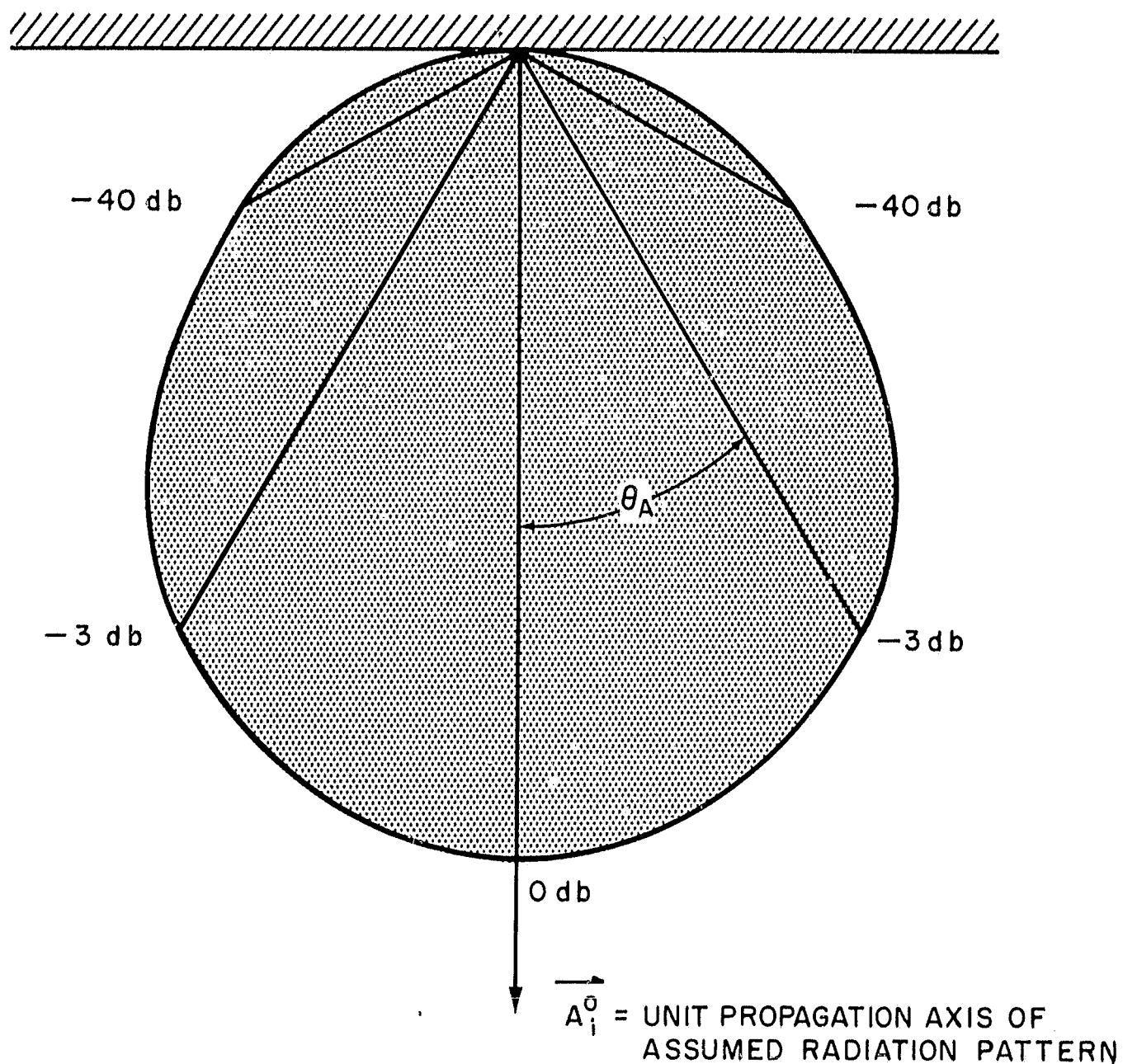


Figure 6—Relationship between antenna gain and "half cone angle" θ_A , for an arbitrary directional antenna

where θ_A is the half cone angle of the effective antenna radiation pattern. The half cone angle of the effective radiation pattern is chosen according to the known antenna characteristics of an arbitrary directional antenna.

2. Omni-directional Antenna: In order to determine "radio" visibility for an omni-direction antenna, it is necessary to calculate ϕ and θ (Ref. 2) which are body fixed angles by which the antenna radiation pattern is described.

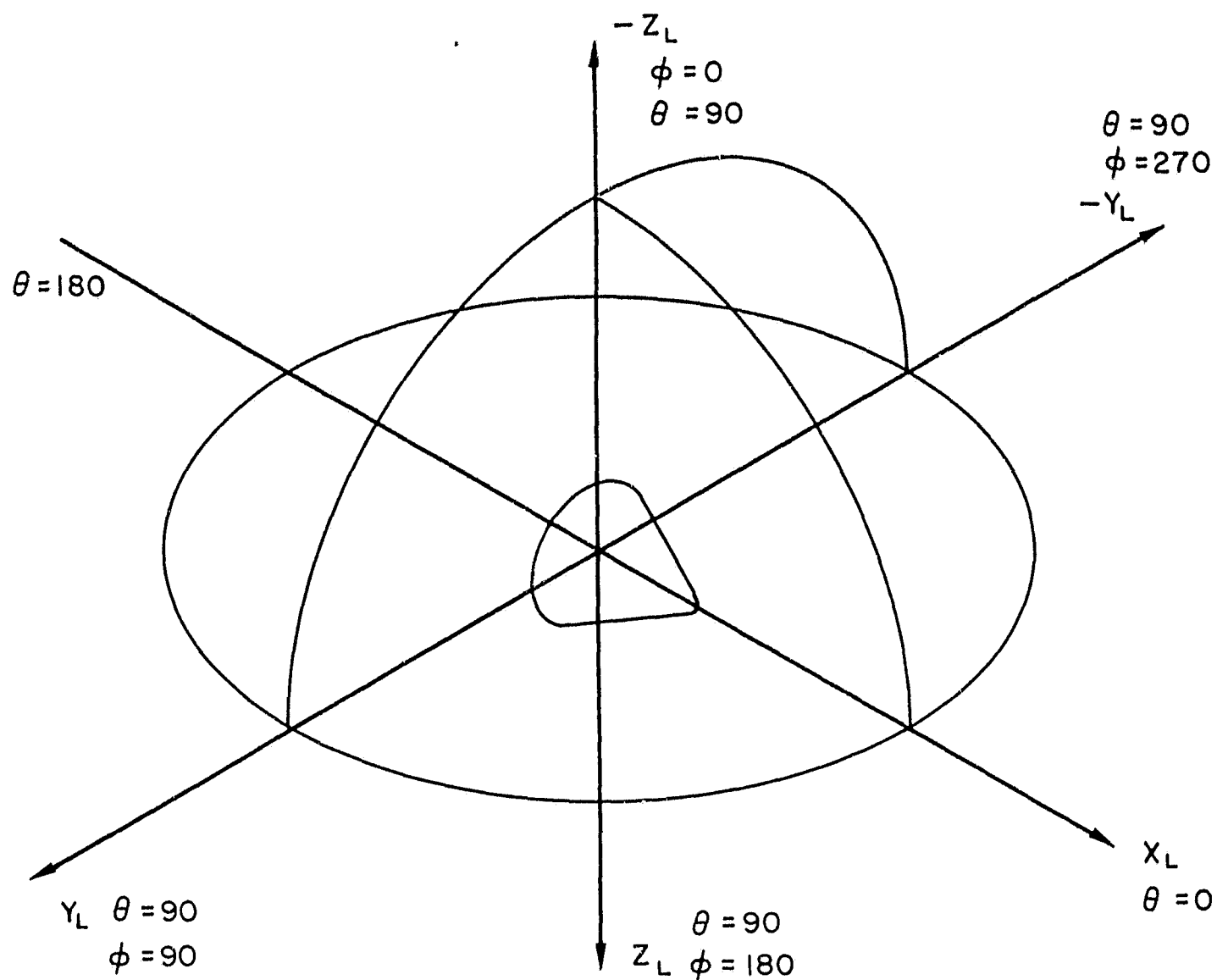


Figure 7—Antenna Radiation Angles ϕ and θ

These angles are expressed in the launch coordinate system

$$\begin{bmatrix} X_L \\ Y_L \\ Z_L \end{bmatrix} = \begin{bmatrix} -X_B \\ -Y_B \\ Z_B \end{bmatrix}_{(3 \times 1)}$$

which is formed by rotating the body axis system 180° about the Z_B axis as

$$\phi = \text{TAN}^{-1} \left(\frac{Y_L}{-Z_L} \right) \quad (13)$$

$$\theta = \text{TAN}^{-1}\left(\frac{X_L}{Z_L}\right) \quad (14)$$

The Antenna Radiation profile for the surviving antenna on the AS-202 is shown in Fig. 8. A plot of the entry time history of ϕ and θ is also shown. Thus, if the transmitting antenna gain is not down by more than 3 db (as in the shaded area) we have good signal strength for receiving.

C. Entry Acquisition

Tracking radar pointing information in terms of azimuth and elevation angles is also provided by the program. These angles are measured in the geodetic coordinate system with origin at the station.

Equation (10) gives us the position vector from station to vehicle in the earth coordinate system. Multiplying by the transpose of equation (6)

$$\vec{R}_{SV_G} = T_{E2G} \vec{R}_{SV_E} \quad (15)$$

The azimuth and elevation angles can be calculated directly from the components of

$$\vec{R}_{SV_G} = \begin{bmatrix} X_G \\ Y_G \\ Z_G \end{bmatrix}_{(3 \times 1)}$$

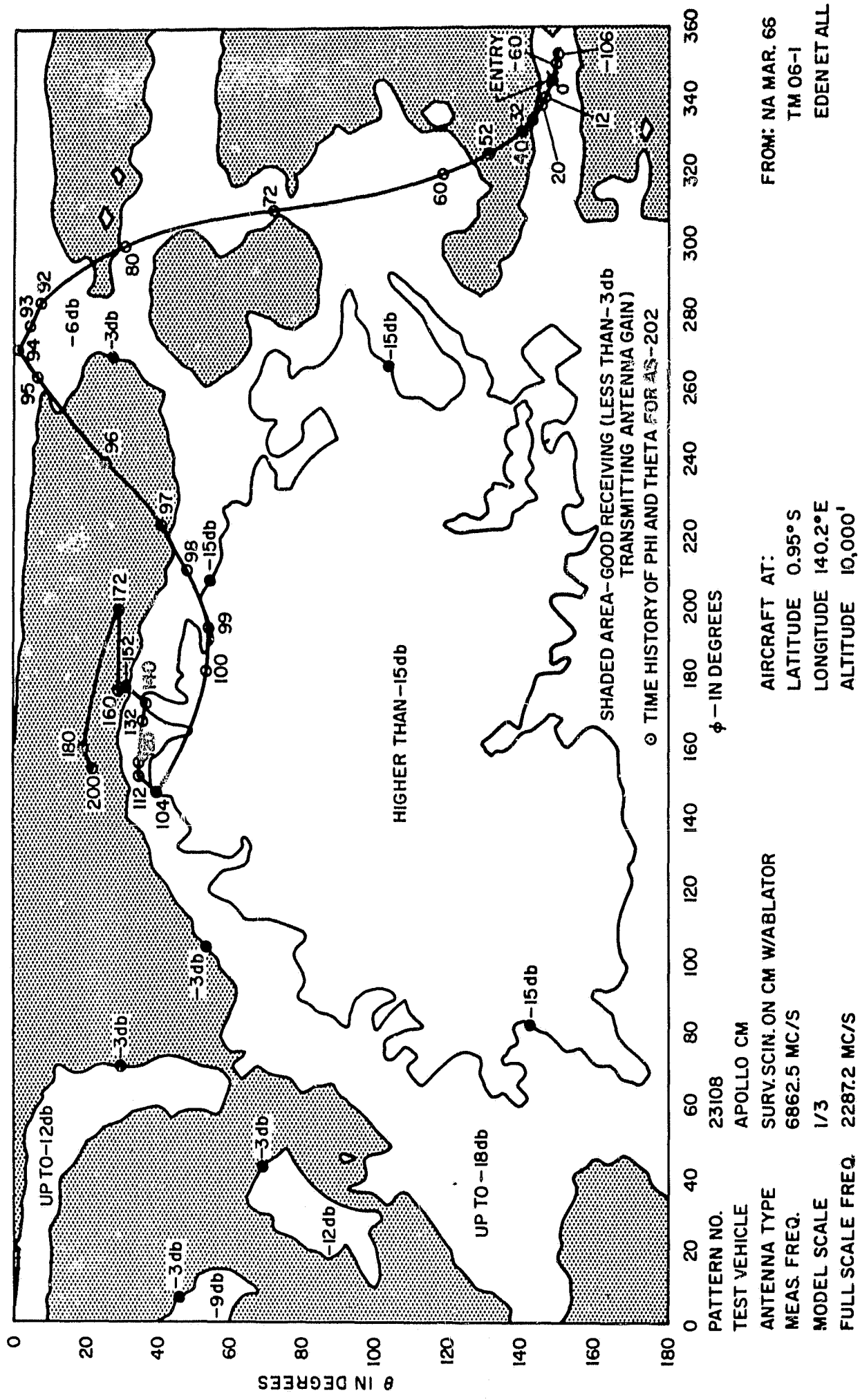


Figure 8—Antenna Radiation Profile Surviving Scin. Antenna Pattern for AS 202

as

$$A_z = \text{TAN}^{-1} \left(\frac{Z_G}{\sqrt{X_G^2 + Y_G^2}} \right) \quad (16)$$

$$E_L = - \text{TAN}^{-1} \left(\frac{Y_G}{X_G} \right) \quad (17)$$

D. Blackout Predictions

A quartic least squares fit was performed on the predicted blackout boundaries (Fig. 9) for VHF, C-Band and S-Band radars. (Ref. 4)

The fit is of the form

$$h_{P_i} = \sum_{j=1}^5 a_j V^{j-1} \quad (18)$$

with the coefficients of the fit being determined from the altitude (h), velocity (V), profiles in (Fig. 9).

The criterion for blackout is

$$h < h_{P_i} \quad (19)$$

where h is the vehicle altitude and i denotes the frequency, i.e., i=1 VHF, i = 2 S-Band, i = 3 C-Band.

II. Program Description

A. Input

The following input data are required for execution of the Entry Acquisition and Radio Visibility Program:

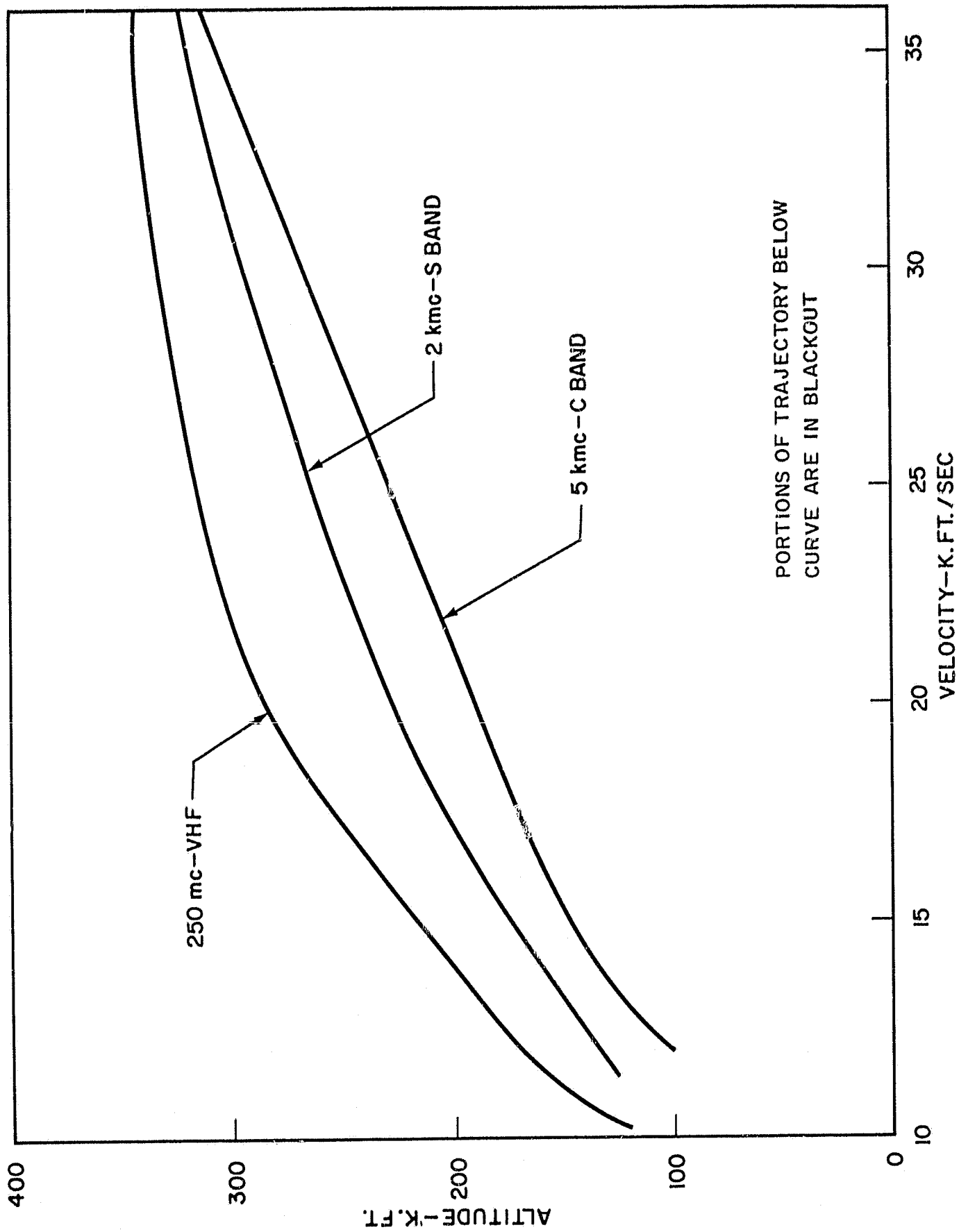


Figure 9—Predicted Blackout Boundaries for 250 mc, 2 kmc, 5 kmc

1. Station

- a. Identification number
- b. Geodetic latitude-degrees
- c. Geodetic longitude-degrees
- d. Altitude-feet

A maximum of 10 stations can be considered per run.

2. Vehicle-borne Antenna

- a. Identification number
- b. Orientation angles

(1) ϕ_i - degrees

(2) θ_b - degrees

A maximum of 8 vehicle antennas can be considered at once.

3. Vehicle Time History Data

- a. Time
- b. Geodetic latitude-degrees
- c. Geodetic longitude-degrees
- d. Altitude - feet
- e. Azimuth - degrees
- f. Flight path angle - degrees
- g. Trim angle of attack - degrees
- h. Bank angle - degrees
- i. Velocity relative to rotating earth - ft/sec.

B. Output

The Entry Acquisition and Radio Visibility Program outputs the following quantities:

1. Primary

- a. Antenna look angle - degrees
- b. Angles θ and ϕ made by station-to-vehicle vector with vehicle - degrees
- c. Indication of Entry Blackout Conditions for VHF, S-Band and C-Band frequencies -

Pr

" / VHF
S-BAND
C-BAND " VISIBLE or

" / VHF
S-BAND
C-BAND " BLKOUT

- d. Station Elevation angle - degrees
- e. Station Azimuth - degrees

2. Secondary

a. Vehicle

(1) Quantities wrt earth coordinate system

- (a) X,Y,Z position coordinates - km
- (b) Longitudinal axis unit vector
- (c) Unit velocity vector

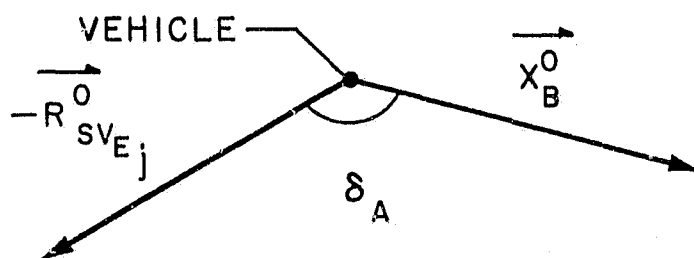
(2) Range along the surface of the earth subtended by the angle between the entry and the i'th position vectors.

b. Station

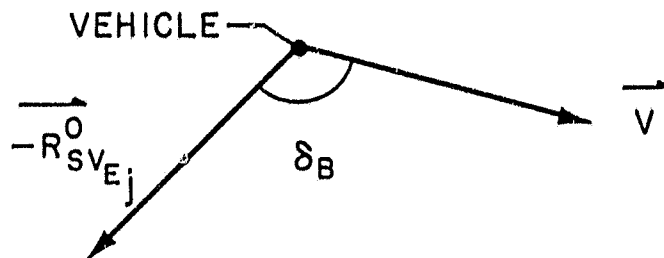
(1) Quantities wrt earth coordinate system

- (a) Position vector - vehicle wrt station - km
- (b) Unit vector - vehicle to station

(2) Aspect angle - degrees



(3) Velocity vector look angle - degrees



(4) Unit vector - vehicle to station in vehicle coordinate system

(5) Ranges - Station to vehicle

- (a) Slant range - nm
- (b) Ground range - nm

c. Vehicle-borne Antenna

Unit propagation axis wrt earth coordinate system

C. Options

Several options can be chosen to suppress execution and output of unwanted portions of the program. The following are the specific options.

1. Suppress velocity vector look angle, aspect angle, unit velocity vector and unit longitudinal axis vector.
2. Suppress antenna look angle and antenna unit propagation axis.
3. Suppress "Blackout" information

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DATA DECK

CARD I Format 415

Control or Option Card

A,B,C,D

A = Number of stations being considered
Maximum of 10

B = Number of vehicle-borne antennas being considered
Maximum of 8

C Selects 3 options

C = 1 Unit Velocity vector, unit longitudinal axis vector, velocity
vector look angle and aspect angle suppressed.

C = 2 Antenna look angle and unit antenna propagation vector suppressed

C = 3 None of above suppressed

D D = 0 Blackout information suppressed

D \neq 0 Blackout information not suppressed

If C = 2, set B = 0.

If C = 1 or 3, B \neq 0.

CARD II Format 2E14.7

Position of vehicle on vehicle ground track at entry.

1. Vehicle geodetic latitude (Deg) at entry
2. Vehicle geodetic longitude (Deg) at entry

CARD III Format I2,3E14.7

Station Input Data

1. Station identification number
2. Geodetic latitude (Deg) - ϕ_G
3. Geodetic longitude (Deg) - λ_G
4. Altitude (ft) - h

One card is submitted for each station with a maximum of 10 stations.

Number of cards must equal item A of Card I.

CARD IV Format I2,2E14.7

Vehicle-borne antenna input data

1. Antenna identification number
2. ϕ_i (Deg)
3. θ_b (Deg)

One card is submitted for each vehicle-borne antenna, with a maximum of 8 antennas. Number of cards must equal item B of Card I. If item C of Card I is set equal to zero, no antenna cards should be submitted.

CARD Va Format 4E14.7

Vehicle Time History Input Data

1. Point in time (data point) - t (sec)
2. Geodetic latitude (Deg) - ϕ_G
3. Geodetic longitude (Deg) - λ_G
4. Altitude (ft) - h

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CARD V_b

1. Azimuth (Deg) - Az
2. Flight path angle (Deg) - γ
3. Trim angle of attack (Deg) - α_T
4. Bank angle (Deg) - β
5. Speed (ft/sec) - V

A set of two cards (Va and Vb) must be submitted for each data point. Item 5 of Card Vb (Speed) can be left blank should item D = 0 for Card I. Should item C = 2 for Card I and ϕ , θ , and longitudinal axis unit vector are not wanted as outputs, items 1, 2, 3, and 4 of Card Vb can be left blank.

Examples

- I. Setup to generate all available outputs for 4 vehicle data points, 3 stations and 2 vehicle antennas.

A. Input data

1. Antenna

ID Nr.	ϕ_i	θ_b
21	+180°	-33°
5	+ 45°	0°

2. Station

ID Nr.	ϕ_G	λ_G	h(ft)
7	-0.95°	140.2°	10,000
6	-2.683°	141.3°	10,000
12	+2.35°	143.15°	8,000

3. Vehicle

Time (data point)	ϕ_G	λ_G	h(ft)	A_z	γ	a_T	β	V(ft/sec)
68.0	-1.9°	140.46°	298,278.0	56.98°	-2.63	-21.9°	180°	27,292.5
72.0	-1.74°	140.71°	293,317.0	56.97°	-2.57	-21.9°	180°	27,294.3
76.0	-1.58°	140.95°	288,469.5	56.95°	-2.51	-21.9°	180°	27,294.6
80.0	-1.42°	141.20°	283,730.2	56.95°	-2.45	-21.9°	180°	27,293.3

4. Entry point on ground track

ϕ_G	λ_G
-4.63°	136.27°

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II. Setup to generate all outputs except antenna look angle and antenna unit propagation axis for a case of 4 data points and 3 stations.

A. Input Data

Station and vehicle data same as for Example I.

B. Card Setup

Card	Column	1	2	5	10	15	17	20	29	31	43	57	Format
Card I				3	0	2		1					4I5
Card II		-4	.63			+136	.27						2E14.7
Card III		7	-0.95				+140	.2		+10000	.0		I2,3E14.7
		6	-2.683				+141	.3		+10000	.0		
		12	+2.35				+143	.15		+8000	.0		
Card Va Vb Va Vb Va Vb Va Vb		68	.0			-1	.9		+1	40	.46	+298278	4E14.7/5E14.7
		+56	.98			-2	.63		-2	1	.9	+180	
		72	.0			-1	.74		+1	40	.71	+293317	
		-56	.97			-2	.59		-2	1	.9	-180	
		76	.0			-1	.58		-1	40	.95	+288469	
		+56	.95			-2	.51		-2	1	.9	+180	
		80	.0			-1	.42		+1	41	.20	+283730	
		+56	.95			-2	.45		-2	1	.9	+180	
												+27292	.5
												+27294	.3
												+27294	.6
												+27293	.3

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III. Setup to generate all outputs except "Blackout" information, aspect angle, velocity vector look angle, longitudinal axis unit vector and velocity unit vector for a case of 4 data points, 3 stations and 2 vehicle antennas.

A. Input Data

Vehicle, station and antenna data same as for Example I.

B. Card Setup

Card Column		5		10		15		20	
Card I		3		2		1		0	
Card II	<div> </div>								
Card III									
Card IV									
Card Va									
Vb									
Va									
Vb									
Va									
Vb									

EXAMPLES OF COMPUTER OUTPUT

Three examples of computer output are included. These examples for a vehicle data point at 72 seconds correspond to the previous data card set-up examples. Note that the output format includes all data that are input to the computer with the data deck.

Example I - All available output data included.

Example II - Vehicle-borne antenna look angle and unit propagation vector suppressed.

Example III - Aspect (Longitudinal axis look angle) angle, velocity vector look angle, longitudinal axis unit vector and unit velocity vector are suppressed.

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COMPUTER OUTPUT
EXAMPLE I
ALL AVAILABLE OUTPUT DATA

STATION LOCATION

STATION	LATITUDE DEG	LONGITUDE DEG	ALTITUDE FT	X KM	Y KM	Z KM
7	-0.9500000E 00	0.1399999E 03	10000.000	-0.48876236E 04	0.41012032E 04	-0.10509176E 03
6	-0.2683000E 01	0.1412999E 03	10000.000	-0.49746680E 04	0.39854610E 04	-0.29670829E 03
12	0.2349999E 01	0.1431499E 03	8000.000	-0.51015446E 04	0.38233912E 04	0.25987909E 03

VEHICLE ANTENNA ORIENTATION ANGLES WRT VEHICLE

ANTENNA	XZ PLANE	YZ PLANE
21	180.000	-33.000
5	45.000	0.

COMPUTER OUTPUT

EXAMPLE I

Cont'd

TIME 72.000

VEHICLE DATA

LATITUDE=-0.17399999E 01 LONGITUDE= 0.14071000E 03 ALTITUDE= 0.29331700E 06
 AZIMUTH= 0.56970000E 02 FLIGHT PATH ANGLE=-0.25699999E 01 THIM ANGLE OF ATTACK=-0.21900000E 02
 BANK ANGLE= 0.18000000E 03 VELOCITY= 0.27294299E 05
 X=-0.50032844E 04 Y= 0.40936831E 04 Z=-0.19508559E 03

RESULTS

VEHICLE

LONGITUDNAL AXIS VECTOR(EARTH)=-0.76912924E 00 -0.39288765E-00 0.50406288E 00
 VELOCITY VECTOR(EARTH)=-0.50847869E 00 -0.66612764E 00 0.54564028E 00
 VEHICLE IS 317.440 NM DOWNRANGE FROM ENTRY

STATION 7

POSITION VECTOR STATION-TO-VEHICLE=-0.11566076E 03 -0.75200500E 01 -0.89993838E 02
 UNIT VECTOR VEHICLE-TO-STATION(EARTH)= 0.78819788E 00 0.51247174E-01 0.61328447E 00
 UNIT VECTOR VEHICLE-TO-STATION(VEHICLE)=-0.31722642E-00 0.79290872E 00 -0.52025285E 00
 PHI= 0.30327016E 03 THETA= 0.58627064E 02
 SLANT RANGE STATION-TO-VEHICLE= 79.234 NM
 GROUND RANGE STATION-TO-VEHICLE= 63.600 NM

STATION 6

POSITION VECTOR STATION-TO-VEHICLE=-0.28616393E 02 0.10822216E 03 0.10162269E 03
 UNIT VECTOR VEHICLE-TO-STATION(EARTH)= 0.18927566E-00 -0.71580724E 00 -0.67215676E 00
 UNIT VECTOR VEHICLE-TO-STATION(VEHICLE)=-0.20315468E-00 -0.81517575E 00 -0.54241726E 00
 PHI= 0.56360238E 02 THETA= 0.69467256E 02
 SLANT RANGE STATION-TO-VEHICLE= 81.636 NM
 GROUND RANGE STATION-TO-VEHICLE= 66.529 NM

STATION 12

POSITION VECTOR STATION-TO-VEHICLE= 0.98260315E 02 0.27029193E 03 -0.45496468E 03
 UNIT VECTOR VEHICLE-TO-STATION(EARTH)=-0.18255749E-00 -0.50217441E 00 0.84527726E 00
 UNIT VECTOR VEHICLE-TO-STATION(VEHICLE)= 0.76378130E 00 0.42898081E-00 -0.48230039E-00
 PHI= 0.31834860E 03 THETA= 0.14772906E 03
 SLANT RANGE STATION-TO-VEHICLE= 290.628 NM
 GROUND RANGE STATION-TO-VEHICLE= 284.839 NM

ANTENNA21 UNIT PROPAGATION AXIS(EARTH)=-0.42380076E-01 0.89211813E 00 -0.44980998E-00

ANTENNA 5 UNIT PROPAGATION AXIS(EARTH)= 0.61905567E 00 -0.26205430E-00 0.74033608E 00

STATION	ELEVATION ANGLE	AZIMUTH	LONGITUDNAL AXIS LOOK ANGLE	VELOCITY VECTOR LOOK ANGLE
7	0.35516912E 02	0.13787991E 03	0.10849527E 03	0.95755654E 02
6	0.34274163E 02	0.32780401E 03	0.10172150E 03	0.89208114E 02
12	0.69089057E 01	0.21100200E 03	0.40201307E 02	0.27307629E 02

ANTENNA LOOK ANGLES

STATION 7

ANTENNA LOOK ANGLE
 21 0.10528062E 03
 5 0.21790801E 02

STATION 6

ANTENNA LOOK ANGLE
 21 0.11013683E 03
 5 0.10112028E 03

STATION 12

ANTENNA LOOK ANGLE

21 0.14513249E 03
 5 0.49881320E 02

VHF BLKOUT SBAND VSIBLE CBAND VSIBLE
 0.314165E 03 0.267883E 03 0.246179E 03

07

COMPUTER OUTPUT
EXAMPLE II
VEHICLE-BORNE ANTENNA LOOK ANGLE AND
UNIT PROPAGATION VECTOR SUPPRESSED

STATION LOCATION

STATION	LATITUDE DEG	LONGITUDE DEG	ALTITUDE FT	X KM	Y KM	Z KM
7	-0.95000000E 00	0.13999999E 03	10000.000	-0.48676236E 04	0.41012032E 04	-0.10509176E 03
6	-0.26830000E 01	0.14129999E 03	10000.000	-0.49746680E 04	0.39854610E 04	-0.29670829E 03
12	0.23499999E 01	0.14314999E 03	8000.000	-0.51015446E 04	0.38233912E 04	0.25987909E 03

COMPUTER OUTPUT

EXAMPLE II

Cont'd

TIME 72.000

VEHICLE DATA

LATITUDE=-0.17399999E 01 LONGITUDE= 0.14071000E 03 ALTITUDE= 0.29331700E 06
 AZIMUTH= 0.56470000E 02 FLIGHT PATH ANGLE=-0.25699999E 01 TRIM ANGLE OF ATTACK=-0.21900000E 02
 BANK ANGLE= 0.18000000E 03 VELOCITY= 0.27294299E 05
 X=-0.50032844E 04 Y= 0.40936831E 04 Z=-0.19508559E 03

RESULTS

VEHICLE

LONGITUDNAL AXIS VECTOR(EARTH)=-0.76912924E 00 -0.39288765E-00 0.50406288E 00
 VELOCITY VECTOR(EARTH)=-0.50847869E 00 -0.66612764E 00 0.54564028E 00
 VEHICLE IS 317.440 NM DOWNRANGE FROM ENTRY

STATION 7

POSITION VECTOR STATION-TO-VEHICLE=-0.11566076E 03 -0.75200500E 01 -0.89993838E 02
 UNIT VECTOR VEHICLE-TO-STATION(EARTH)= 0.78819788E 00 0.51247174E-01 0.61328447E 00
 UNIT VECTOR VEHICLE-TO-STATION(VEHICLE)=-0.31722648E-00 0.79290872E 00 -0.52025285E 00
 PHI= 0.30327016E 03 THETA= 0.58627064E 02
 SLANT RANGE STATION-TO-VEHICLE= 79.234 NM
 GROUND RANGE STATION-TO-VEHICLE= 63.600 NM

STATION 6

POSITION VECTOR STATION-TO-VEHICLE=-0.28616393E 02 0.10822216E 03 0.10162269E 03
 UNIT VECTOR VEHICLE-TO-STATION(EARTH)= 0.18927566E-00 -0.71580724E 00 -0.67215676E 00
 UNIT VECTOR VEHICLE-TO-STATION(VEHICLE)=-0.20315488E-00 -0.81517575E 00 -0.54241726E 00
 PHI= 0.56360238E 02 THETA= 0.69467256E 02
 SLANT RANGE STATION-TO-VEHICLE= 81.636 NM
 GROUND RANGE STATION-TO-VEHICLE= 66.529 NM

STATION 12

POSITION VECTOR STATION-TO-VEHICLE= 0.98260315E 02 0.27029193E 03 -0.45496468E 03
 UNIT VECTOR VEHICLE-TO-STATION(EARTH)=-0.18255749E-00 -0.50217441E 00 0.84527726E 00
 UNIT VECTOR VEHICLE-TO-STATION(VEHICLE)= 0.76378130E 00 0.42898061E-00 -0.48230039E-00
 PHI= 0.31834860E 03 THETA= 0.14772906E 03
 SLANT RANGE STATION-TO-VEHICLE= 290.628 NM
 GROUND RANGE STATION-TO-VEHICLE= 284.839 NM

STATION	ELEVATION ANGLE	AZIMUTH	LONGITUDNAL AXIS LOOK ANGLE	VELOCITY VECTOR LOOK ANGLE
7	0.35516912E 02	0.13787991E 03	0.10849527E 03	0.95755654E 02
6	0.34274163E 02	0.32780401E 03	0.10172150E 03	0.89208114E 02
12	0.69089057E 01	0.21100200E 03	0.40201307E 02	0.27307629E 02

VHF BLKOUT SBAND VSIBLE CBAND VSIBLE
 0.314165E 03 0.267883E 03 0.246179E 03

PP

COMPUTER OUTPUT

EXAMPLE III

ASPECT ANGLE, VELOCITY VECTOR LOOK ANGLE, LONGITUDINAL
AXIS UNIT VECTOR UNIT VELOCITY VECTOR
AND BLACKOUT INFORMATION SUPPRESSED

STATION LOCATION

STATION	LATITUDE DEG	LONGITUDE DEG	ALTITUDE FT	X KM	Y KM	Z KM
7	-0.95000000E 00	0.13999999E 03	10000.000	-0.48876236E 04	0.41012032E 04	-0.10509176E 03
6	-0.26830000E 01	0.14129999E 03	10000.000	-0.49746680E 04	0.39854610E 04	-0.29670829E 03
12	0.23499999E 01	0.14314999E 03	8000.000	-0.51015446E 04	0.38233912E 04	0.25987909E 03

VEHICLE ANTENNA ORIENTATION ANGLES WRT VEHICLE

ANTENNA	XZ PLANE	YZ PLANE
21	180.000	-33.000
5	45.000	0.

COMPUTER OUTPUT

EXAMPLE III

Cont'd

TIME 72.000

VEHICLE DATA

LATITUDE=-0.17399999E 01 LONGITUDE= 0.14071000E 03 ALTITUDE= 0.29331700E 06
 AZIMUTH= 0.56970000E 02 FLIGHT PATH ANGLE=-0.25699999E 01 TRIM ANGLE OF ATTACK=-0.21900000E 02
 BANK ANGLE= 0.18000000E 03 VELOCITY= 0.27294299E 05
 X=-0.50032844E 04 Y= 0.40936831E 04 Z=-0.19508559E 03

RESULTS VEHICLE

STATION 7

POSITION VECTOR STATION-TO-VEHICLE=-0.11566076E 03 -0.75200500E 01 -0.89993838E 02
 UNIT VECTOR VEHICLE-TO-STATION(EARTH)= 0.78819788E 00 0.51247174E-01 0.61328447E 00
 UNIT VECTOR VEHICLE-TO-STATION(VEHICLE)=-0.31722648E-00 0.79290872E 00 -0.52025285E 00
 PHI= 0.30327016E 03 THETA= 0.58627064E 02
 SLANT RANGE STATION-TO-VEHICLE= 79.234 NM
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STATION 6

POSITION VECTOR STATION-TO-VEHICLE=-0.28616393E 02 0.10822216E 03 0.10162269E 03
 UNIT VECTOR VEHICLE-TO-STATION(EARTH)= 0.18927566E-00 -0.71580724E 00 -0.67215676E 00
 UNIT VECTOR VEHICLE-TO-STATION(VEHICLE)=-0.20315488E-00 -0.81517575E 00 -0.54241726E 00
 PHI= 0.56360238E 02 THETA= 0.69467256E 02
 SLANT RANGE STATION-TO-VEHICLE= 81.636 NM
 GROUND RANGE STATION-TO-VEHICLE= 66.529 NM

STATION 12

POSITION VECTOR STATION-TO-VEHICLE= 0.98260315E 02 0.27029193E 03 -0.45496468E 03
 UNIT VECTOR VEHICLE-TO-STATION(EARTH)=-0.18255749E-00 -0.50217441E 00 0.84527726E 00
 UNIT VECTOR VEHICLE-TO-STATION(VEHICLE)= 0.76378130E 00 0.42898061E-00 -0.48230039E-00
 PHI= 0.31834860E 03 THETA= 0.14772906E 03
 SLANT RANGE STATION-TO-VEHICLE= 290.628 NM
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ANTENNA21 UNIT PROPAGATION AXIS(EARTH)=-0.42380076E-01 0.89211813E 00 -0.44980998E-00

ANTENNA 5 UNIT PROPAGATION AXIS(EARTH)= 0.61905567E 00 -0.26205430E-00 0.74033608E 00

STATION	ELEVATION ANGLE	AZIMUTH
7	0.35516912E 02	0.13787991E 03
6	0.34274163E 02	0.32780401E 03
12	0.69089057E 01	0.21100200E 03

ANTENNA LOOK ANGLES

STATION 7

ANTENNA	LOOK ANGLE
21	0.10528062E 03
5	0.21790801E 02

STATION 6

ANTENNA	LOOK ANGLE
21	0.11013683E 03
5	0.10112028E 03

STATION 12

ANTENNA	LOOK ANGLE
21	0.14513249E 03
5	0.49881320E 02

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3. Dennison, A. J., and Butler, J. F., Missile and Satellite Systems Program for the IBM 7090, G.E. T1S61SD170, February, 1962.
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